NEUTRALIZATION IN AZTEC PHONOLOGY – THE CASE OF CLASSICAL NAHUATL NASALS[1]

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Abstract
This article investigates nasal assimilation in Classical Nahuatl. The distribution of nasal consonants is shown to be the result of coda neutralization. It is argued that generalizations made for root and word level are disproportionate and cannot be explained through the means of rule-based phonology. It is shown that the process responsible for nasal distribution can only be accounted for by introducing derivational levels in Optimality Theory.

Keywords: Classical Nahuatl, derivational optimality theory (DOT), coda neutralization, nasal assimilation

1. Introduction

This article offers a phonological account of a previously unrecognized pattern in the distribution of nasal segments in Classical Nahuatl, a language used in the Aztec Empire (and later in Mexico) at the time of the Spanish conquest and in the following centuries, during which it systematically split into numerous dialects. Additionally, on the theoretical side, the article reviews a selection of analytical approaches to the data, couched in different generative frameworks. Finally, it offers an argument for the relevance of derivational levels.

Classical Nahuatl consonantal inventory contains two nasal phonemes: labial [m] and alveolar [n]. Each of them has its own distributional pattern. The distribution of [m] seems to be more limited than the distribution of [n]. The prevocalic position is available to both nasals, within morphemes and across morpheme boundaries, however, the pre-consonantal position is somewhat restricted. The labial nasal [m] can only appear before other labial consonants. The alveolar nasal has to be followed by a non-labial consonant morpheme-internally, but across morpheme boundaries it can be found before any consonant, including a labial one. Finally, the labial nasal cannot stand in the word-final position, while the alveolar one faces no such limitations.

[1] I would like to thank Joanna Zaleska and two anonymous Research In Language reviewers for their discussion and criticism which led to considerable improvements of both the content and the presentation of my analysis. However, the responsibility for this article is solely mine.

The article shows that this distribution of nasals is readily accounted for in the model of standard generative phonology as developed by Chomsky and Halle (1968; SPE henceforth). Nevertheless, the rules that need to be posited carry little explanatory power. An improvement can be made if the hierarchical representation of the syllable is recognized. This makes it possible to motivate the behaviour of nasals by place restrictions of coda positions. If it is further assumed that not only syllables but also features are hierarchically organized it is possible to unify a number of processes and express them in terms of natural rules of spreading and delinking. An analysis couched within Optimality Theory (Prince and Smolensky 1993; McCarthy and Prince 1995; OT henceforth) shows the Classical Nahuatl data in a broader context, as the triggers of assimilation and neutralization can now be expressed as universal constraints on coda consonants. Finally, it is found that there is an asymmetry between morpheme-internal and morpheme-final codas, which may be easily expressed if we assume the well-supported distinction between the stem and word level, on which various processes may behave in different ways.

This article is organized as follows. Section 2 states the descriptive generalizations governing the distribution of nasal consonants. Section 3 shows how those generalizations are expressed in terms of SPE phonology. The section begins with an analysis set in the classic SPE model of feature matrices, through which relevant features taking part in the processes are recognized. Later it is shown that by introducing the syllable structure, the environment for the processes may be fully stated. This is followed by the implementation of the autosegmental model of hierarchically ordered features, through which it is possible to understand the nature of processes governing nasal distribution and express them in the form of delinking and spreading of bundles of features. Section 4 offers a revision of the analysis in the framework of OT. First, constraints needed to account for the generalizations made in section 2 are presented. The presentation is then followed by postulating a possible constraint ranking governing the distributional pattern of nasal consonants. It is soon noticed that standard OT cannot account for the generalizations made for the stem and the word levels simultaneously. The only solution is to recognize levels of derivation. Section 5 provides a conclusion and directions for further research.

2. The distribution of nasal consonants in Classical Nahuatl

The known sound inventory of Classical Nahuatl consists of eight vowels (1a) and fifteen consonants (1b):

(1) Phoneme inventory of Classical Nahuatl (Andrews 2003)
a. vowels: i, i:, e, e:, a, a:, o, o:
b. consonants: p, m, t, s, ts, n, l, tɬ, ʃ, tʃ, j, k, k^w, w, ʔ

Since the language is no longer in use, it is impossible to either prove or disprove the existence of any contextual variants of the phonemes listed in (1). For the purposes of this paper, (1) will be assumed to be an exhaustive list of sounds used by speakers of the language. All examples used in this article come from contemporary Classical Nahuatl grammars: *Nahuatl as Written…* (henceforth: NW) by Lockhart (2001) and *Foundation Course in Nahuatl Grammar* (henceforth: FCNG) by Campbell and Karttunen (1989). These sources have been chosen in order to use unified forms and avoid misspelled words, often found in original manuscripts.

The Classical Nahuatl consonantal inventory contains two nasal phonemes: labial [m] and alveolar [n].[2] The (near) minimal pairs in (2) show that the two segments function contrastively.

(2) Contrastive nasal consonants in Classical Nahuatl
a. āmatl [a:ma+tɬ] "paper, document"
āna [a:na] "to stretch, to grow" (NW: 210, 211)
b. mo [mo] 2 SING POSS[3] prefix
no [no] 1 SING POSS prefix (NW: 225, 227)
c. nicmaca [ni+k+maka] "I give him"
nicnequi [ni+k+neki] "I need it" (NW: 19, 9)

The contrast between [m] and [n], however, is only found in the prevocalic environment. In other contexts, the distribution of nasals is restricted. Word-finally, only [n] appears.

(3) Word-final nasal consonants in Classical Nahuatl
a. in [in] particle/subordinator/article (NW: 220)
b. pan [pan] "on, in" (NW: 229)

Words analogous to those in (3) but containing bilabial nasals, such as *[im] or *[pam], are never found. Moreover, we may notice some alternations between the two nasal segments. For example, when the morpheme *nemi* [nemi] ("to live") loses its final vowel while forming the preterite form,[4] the word final segment surfaces as [n], while it is realized as [m] in the present form (4).

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2 Andrews (2003) claims that there are four nasal phones in Classical Nahuatl: [n], [m], [ŋ] and [n̥]. Since he gives no references in this regard, it must be assumed that those phones were deducted from descriptions made by first Classical Nahuatl grammarians, such as Carochi (1645/2001). Andrews himself notes that such descriptions may be unreliable, and gives the example of Carochi's most probably incorrect assumption that there are two allophones of [ʔ] (Andrews 2003: 25). Given that, I will rely solely on the phonemic inventory.

3 The following abbreviations will be used throughout: 1 = first person, 2 = second person, SING = singular, PL = plural, SUB = subject, POSS = possessive.

4 Class 2 verbs, such as *nemi*, create preterite forms by dropping their final vowel (Lockhart 2001: 33).

(4) Word-final nasal alternations
a. nemi [nemi] "He/She lives"
b. nen [nen] "He/She lived" (FCNG: 29)

Other distributional differences between those two nasal consonants involve their position before other consonants. It appears that the labial nasal [m] can only be found before other labials (5a,b), while only [n] occurs before non-labial consonants (5c,d).

(5) Morpheme-internal distribution of nasals
a. pampa[5] [pampa] "on behalf of" – *panpa [panpa] (NW: 229)
b. imman [imman] "time to do something" – *inman [inman] (NW: 220)
c. cenkah [senkaʔ] "very, greatly" – *cemkah [semkaʔ] (NW: 213)
d. intlā [intła:] "when" – *imtlā [imtła:] (NW: 220)

Across morpheme boundaries, we may find alternations between [m] and [n] in the pre-consonantal position. One example involves the 2 PL SUB prefix *am-/an-* which surfaces as [am] before vowels and bilabial consonants,[6] and as [an] before any non-bilabial consonants. This is illustrated by examples in (6).

(6) Word-internal alternations of *am-/an-*
a. ammotta [am+mo+tta+ʔ] "You (PL) see yourselves"(NW:10)
ampāquih [am+pa:ki+ʔ] "You (PL) are happy" (FCNG: 105)
amatlaca [am+a+tłaka] "You (PL) are bad people" (NW: 3)
b. annemi [an+nemi+ʔ] "You (PL) live" (NW: 3)
antlaca [an+tłaka] "You (PL) are people (NW: 2)
anquitta [an+k+itta+ʔ] "You (PL) see it" (NW: 10)
anyezque [an+je+s+keʔ] "You (PL) will be" (NW: 65)

Other prefixes, such as the 3 PL POSS prefix *im-/in-*, exhibit the same alternations as *am-/an-*. However, there exists a prefix that does not alternate. As shown in (7), the morpheme-final alveolar nasal [n] in the directional prefix *on-* is always realized as the same segment, whether the following sound is a vowel (7a), a labial consonant (7b) or a non-labial consonant (7c,d).

5 At this point, an issue of etymology must be addressed. It appears to be a common notion among Classical Nahuatl scholars, best reflected in Karttunen's dictionary (1992), that polysyllabic words such as *pampa* are being derived from monosyllabic roots, often with little or no regard to their meaning. While a diachronic view might postulate such mechanism, treating polysyllabic words as compounds synchronically is unjustified.

6 Since no words native to Classical Nahuatl begin with [l], and [ʔ] may only appear in the coda, it may be assumed that am-/an- never connects with either of those two sounds.

(7) The representation of *on-* in various environments
a) onaci [on+aʔsi] "He/she arrives there"
b) conmaca [k+on+maka] "He gives it to him"
c) conhuica [k+on+wika] "He/she takes it away" (NW: 14)
d) onquīzah [on+ki:sa+ʔ] "They emerge thither, away from here" (FCNG: 174)

The prefixes *am-/an-* and *on-* have the same form: they both consist of a vowel followed by a nasal segment. Additionally, they are both prefixes which may be added to a verbal root. Yet only the former exhibits alternations, while the latter never does. As noted before, the spelling system of Classical Nahuatl was often inconsistent. Consequently, alternations of *on-* might have never been reflected in writing. However, as noticed by Lockhart (2001), the other prefixes were often spelled with a *m* before other labials. Andrews (2003) assumes that while alternations of *on-* were not written, they must have been present due to the processes which he vaguely describes (Andrews 2003: 36-37). As stated before, the data used in this article are based on the spelled forms. Since the written sources mostly used the *on-* form, it will be assumed that the spelling reflects the pronunciation.

It should also be noted at this point that it is not certain whether the sound preceding the velar [k] in [ankittaʔ] in (6) is [n] or the velar [ŋ]. The fact that Classical Nahuatl is no longer in use forces us to rely solely on the written sources, which lack clear evidence for the existence of the velar nasal in the language. This absence may result from the fact that the writing system of Nahuatl was developed through cooperation with Spanish monks, and is in fact based on Spanish spelling (Lockhart, 2001). The contemporary Spanish sound system itself lacks a phonemic velar nasal, but it does have an allophonic one which is the result of Nasal Velarization (Hammond, 2001; Salcedo, 2010) and is not reflected in spelling. As the aim of this paper is not to postulate new hypothetical segments in Classical Nahuatl, it will be assumed that there is no velar nasal in Classical Nahuatl and, in consequence, the sound preceding the velar stop [k] is the alveolar nasal, as suggested by the spelling. 7

To sum up, the distribution of [m] seems to be more limited than the distribution of [n]. The prevocalic position is available to both nasals, within morphemes (2), and across morpheme boundaries (6a, 7a), however the pre-consonantal position is not. The labial nasal [m] can only appear before other labial consonants (5a,b; 6a,b). The alveolar nasal has to be followed by a non-labial consonant morpheme-internally (5c,d), but across morpheme boundaries it can be found before any consonant, including a labial one (6b, 7). Finally, the labial nasal cannot stand in the word-final position, while the alveolar one faces

[7] As noted by an anonymous reviewer, the absencje of the velar nasal is not unusual and can also be found in Russian.

no such limitations (3,4). The distribution of the two sounds is summarized in Table. 1.

Table 1. The distribution of nasal segments

	__V	__LABIAL	__NONLABIAL
Morpheme-internally	n, m	m	n
Across morpheme boundaries	n, m	n, m	n
Word-finally	n		

The following sections offer an analysis of this complex distribution of alveolar and bilabial nasals in Classical Nahuatl within the generative framework.

3. Rule-based analysis

This section will be devoted to a rule-based analysis of the data presented above, based on the model introduced by Chomsky and Halle in *The Sound Pattern of English* (SPE; 1968). The main point of the SPE framework is the assumption that each morpheme has a unique underlying representation (henceforth: UR).[8] The UR is a base for a set of phonological rewrite rules, which reflect generalizations made about the distribution of sounds or alternations found in a language.

Each segment can be described through an unordered set of binary distinctive features (e.g. [±nasal]). The schematic representation of a phonological rule uses the distinctive features, although it is also acceptable to use the segment symbol itself for shorter notation (when possible). Due to the fact that all alternations presented so far concern the place features, it may be useful to recall how SPE describes particular places of articulation in terms of features (Tab. 2).

Table 2. Place of articulation distinctive features of Nahuatl consonants (based on SPE: 307)[9]

Place	anterior	coronal	high	low	back	sounds
Labial	+	–	–	–	–	p, m
Alveolar[10]	+	+	–	–	–	t, s, ts, n, tɬ
Palato-Alveolar	–	+	+	–	–	ʃ, tʃ
Palatal	–	–	+	–	–	j
Velar	–	–	+	–	+	k, w

8 Throughout the paper, the following notation of sound representation will be used: // // = the UR, / / = an intermediary stage of derivation, [ ] = the SR.

9 Due to distributional limitations [l] and [ʔ] sounds are not included.

10 SPE makes no distinction between *dentals* and *alveolars* and collectively calls them *dentals*. However, looking at the sounds of Classical Nahuatl falling into this category, it seems more appropriate to call them *alveolars*.

3.1. Prevocalic nasals

Since rules apply to the underlying representation, the first step of the analysis is establishing the URs of morphemes containing nasal segments, introduced in section 2. In the case of morphemes such as those presented in (2), the task is simple as their UR and surface representations (henceforth: SR) are identical[11]. Such a conclusion can be reached by noticing that different nasal segments can be found in the same environment, e.g. in the (1a) [a:na] and [a:ma] pair there are two distinct nasal consonants in the same context [a:__a]. If these words had the same UR, a rule would have to apply in order to generate a SR that does not match the UR. However, when the contextual requirements are met, a rule always generates the same SR, which in this case would be the same nasal segment. If those two morphemes had the same UR, they would also have identical SRs – whether the rules applied or not. Consequently, [a:na] and [a:ma] have different underlying representations, which are identical to their surface forms.

3.2. Word-final nasals

In the case of *nemi*, establishing the underlying representation is not quite straightforward, since the word has two surface forms (4), which means that two URs are conceivable: //nemi//, with a bilabial nasal, and //neni//, with an alveolar nasal. If the underlying representation of *nemi* were //neni//, the present form [nemi] would have to be derived by a rule of Nasal Labialization (8), turning the alveolar nasal into the labial one:

(8) Nasal Labialization (incorrect)
$n \rightarrow m$ / __ i

Such a rule does not exist in Classical Nahuatl, since there are words such as *mani* [mani] "to be extended over a flat surface" (NW 224), which would have to be realized as *[mami]. It is therefore not possible to derive [nemi] from the assumed UR, which means that //neni// cannot be the correct underlying representation of this morpheme. Consequently, the other proposed UR, //nemi//, must be the correct one.

After the present form drops the final vowel to create the preterite form, it is subjected to the rule of Final Nasal Delabialization (9), which changes the place of articulation of word final nasals from bilabial to alveolar:

11 As noted by an anonymous reviewer, UR and SR are never identical and differ e.g. in terms of abstractness. The term "identical" is used here refers only to the sounds present in both forms and is thus an approximation.

(9) Final Nasal Delabialization

$$[+\text{ nasal}] \rightarrow [+\text{ coronal}] \ / \ \_\_\#$$

Therefore, [nen] is derived from //nemi// in the following way:

(10) Derivation of the preterite form of *nemi*
//nem//[12]
/nen/ | Final Nasal Delabialization
[nen]

The rule postulated in (9) explains not only the alternation in question, but also the absence of words ending with a labial nasal, such as the examples shown in (3).

3.3. Word-internal nasals

Another alternation between [m] and [n] that needs to be accounted for is found in some of the prefixes. Since the directional prefix *on*- exhibits no alternations, it may be assumed that its UR is //on// and that no rules are needed to generate its SR. The 2 PL SUB prefix *am-/an-* (6), on the other hand, has two surface forms, [am] and [an], which need to be accounted for. Again, there are two possible underlying representations which need to be investigated: //an// and //am//. If the former were correct and the morpheme contained the alveolar nasal, a rule would be necessary to change the alveolar nasal into the labial one before vowels and labial consonants. Since consonants and vowels do not constitute a natural class, a single phonological rule could not account for the change. As a result, two separate rules would be necessary – one applying before consonants (11), and another one before vowels (12).

(11) Nasal Labialization (incorrect)

$$n \rightarrow m \ / \_\_ \begin{bmatrix} +\text{ anterior} \\ -\text{ coronal} \end{bmatrix}$$

Rule (11) would explain the existence of words such as *ammotta* [ammottaʔ] and *ampāquih* [ampa:kiʔ] in (6), but it would also derive an incorrect *[kommaka] instead of the attested [konmaka] (cf. 7b). Additionally, if //an// were the correct UR, it would also have to be the base for the prevocalic [am]. The surface form could be achieved by postulating a rule of Prevocalic Nasal Labialization (12).

12 This cumulative UR is the result of the application of the preterite word formation rule to //nemi//.

(12) Prevocalic Nasal Labialization (incorrect)
$n \rightarrow m$ / __V

Such a rule would disallow any [nV] sequence, meaning that any nasal preceding a vowel would have to be realized as [m]. This is clearly not the case, as the forms in (2) and (7) demonstrate. Therefore, the rule cannot be correct. As there is no way of producing [m] from the proposed UR, //an// cannot be the correct underlying representation. The correct UR of the morpheme *am-/an-* is therefore //am// and this must be the base for derivation of the observed forms presented in (6).

The underlying //m// sound surfaces with the labial place of articulation only before vowels and other labial consonants. Elsewhere, that is, before non-labial consonants, it is realized as [n]. However, it is not possible to create a rule with a negative context (A → B when *not* X__Y). Non-labial consonants: alveolars, palato-alveolars, palatals and velars do not constitute a natural class. The alternations would have to be expressed in terms of two rules: Pre-Coronal Nasal Delabialization (13), to account for the change before alveolars and palato-alveolars, and Pre-Dorsal Nasal Delabialization (14), for alternations occurring before palatals and velars.

(13) Pre-Coronal Nasal Delabialization
$m \rightarrow n$ / __[+coronal]

(14) Pre-Dorsal Nasal Delabialization

$$m \rightarrow n \;/\; \_\_ \begin{bmatrix} -\text{anterior} \\ -\text{coronal} \end{bmatrix}$$

As shown in (15), the rules in (13) and (14) generate the attested SRs.

(15) Application of the Nasal Delabialization rules (13, 14)

//am+tlaka//	//am+k+itta+ʔ//	
/antlaka/	-----	| Pre-Coronal Nasal Delabialization
-----	/ankittaʔ/	| Pre-Dorsal Nasal Delabialization
[antlaka]	[ankittaʔ]	

The rules proposed in (13) and (14) are observationally adequate as they generate all and only the correct surface forms. For the //am// prefix, they generate a surface form with an alveolar nasal before non-labials. The rules, applicable to forms with the bilabial nasal, do not affect the directional prefix *on-* since it has an alveolar nasal in its UR. This explains the lack of alternations in (7).

3.4. Unifying the rules

Sections 3.2 and 3.3 have shown that the alternations in (4) and (6) are essentially of the same nature. In all cases, an underlying bilabial nasal is turned into an alveolar one. Despite this similarity, three separate rules had to be posited in order to account for the change: Final Nasal Delabialization (9), Pre-Coronal Nasal Delabialization (13) and Pre-Dorsal Nasal Delabialization (14). The SPE model makes it impossible to merge these three rules into one, as their contexts do not share distinctive features which would allow such a unification. As a result, in spite of its descriptive adequacy, from the point of view of economy of description, the account presented above is hardly satisfactory.

However, if we go beyond the strict SPE framework, as presented by Chomsky and Halle (1968), one can find a common denominator that ties together the three. A closer look at the syllabification of words involved in the alternations reveals that every time a nasal changes its place of articulation, the segment is syllable-final. Thus, it can be noticed that when *nemi* [ne.mi] (5) loses its word-final vowel, the bisyllabic word becomes monosyllabic. As a result, the alternating nasal moves from the syllable-initial to syllable-final position. The same can be observed for words in which the alternating nasal is word-medial (6). Languages may differ in the way they syllabify words, however, as convincingly shown by Canger (1980), Classical Nahuatl keeps a CVC.CVC syllable structure. Consequently, the syllabification of words containing word-medial nasal segments is as shown in (16).

(16) Syllabification of words containing coronal nasal segments
[an.ne.miʔ] "You (pl) live"
[an.tła.ka] "You (pl) are people"
[an.kit.taʔ] "You (pl) see it"
[an.jes.keʔ] "You (pl) will be"

Here, too, the alternating nasal stands in the syllable-final position. To sum up, it appears that what all alternating nasals have in common is their position within the syllable. It could then be assumed that syllabification is the real source of all nasal alternations in Classical Nahuatl.

Originally, the syllable was not part of the SPE framework, which excluded the prosodic structures from the generative analysis (SPE: 329). SPE assumed that all rules can be successfully postulated using features only, so including an additional structure would go against the principle of ontological parsimony. However, it soon became apparent that including the syllable into the generative analysis can elegantly account for various processes, such as stress assignment or distributional restrictions on segments (Kahn 1976).

Using the coda position as the environment for alternation, a rule of Coda Delabialization (18) can be proposed.

(18) Coda Delabialization
[+ nasal] → [+ coronal] / __ $)_\sigma$

Rule (18) would successfully operate on examples exhibiting final delabialization (4) and word-internal nasal alternations (6b), which is shown in (19).

(19) The application of Coda Delabialization rule (18)
a. Word-finally b. Word-internally

//nem// //am+k+itta+ʔ//
/nem/ /am.kit.taʔ/ | *Syllabification*
/nen/ /an.kit.taʔ/ | Coda Delabialization
[nen] [an.kit.taʔ]

The proposed rule of Coda Delabialization (18) generates proper SRs in the examples above. However, the rule would also apply to nasals in the pre-labial environment, such as those in (6a), as shown in (20).

(20) The application of Coda Delabialization (18) to pre-labial nasals (6a)

// am+pa:ki+ʔ//
/am.pa:.kiʔ/ | *Syllabification*
[an.pa:.kiʔ] | Coda Delabialization

Since the rule of Coda Delabialization operates each time a labial nasal is found in the coda position, the pre-labial position cannot save the sound from changing its place of articulation. In order to produce a labial nasal in the pre-labial environment, the previously postulated rule of Nasal Labialization (11) must apply, as shown in (21).

(21) The derivation of words containing *am-* in pre-labial environment
// am+pa:ki+ʔ//
/am.pa:.kiʔ/ | *Syllabification*
/an.pa:.kiʔ/ | Coda Delabialization
[am.pa:.kiʔ] | Nasal Labialization

The rule of Nasal Labialization operates every time it encounters an alveolar nasal before a labial consonant. However, the example presented by the prefix *on-* (7) and the fact that it exhibits no alternations in any context shows that such a rule cannot be applied. If the rule were to be applied to a word containing the directional prefix *on-* in a pre-labial context, it would produce *[om] on the surface.

(22) The derivation of a word containing *on-* in pre-labial position
//k+on+maka//
/kon.ma.ka/ | *Syllabification*
----- | Coda Delabialization
*[kom.ma.ka] | Nasal Labialization

When the directional prefix *on-* or the 2 PL SUB prefix *am-* stand before a word-initial [m] (as in [maka] and [motta]), they share the same environment: the coda position and a following labial nasal. When Coda Delabialization causes syllable final [m] to change into [n], the difference between the directional prefix *on-* and the 2 PL SUB prefix *am-* is neutralized and they are recognized by further rules equally. It is not possible to limit Nasal Labialization only to those alveolar nasals which are products of other rules, so that an underlying alveolar nasal would stay unchanged.

The only way to salvage the syllable-based analysis would be to state that the directional prefix *on-* is marked as exceptional. This exceptionality could then be used to explain its lack of alternations by arguing that it does not undergo nasal labialization. A word that would support this hypothesis is *tēmpoloā* [te:mpoloa:] "to stammer" (Karttunen 1992: 224), derived from *tēn+tli* [ten+tɬi] "lip, mouth, edge" (Karttunen 1992: 226) and *poloā* [poloa:] "to perish, to be destroyed" (Karttunen 1992: 202). The final //n// of *ten-* seems to change its place of articulation to labial in order to match the place feature of the initial labial plosive in *poloa* suggesting that *on-* is indeed an exception and coronals at the end of other prefixes do assimilate. If the final nasal in *ten-* were in fact the labial //m//, the absolutive form would be formed by adding another suffix *–itl* (FCGN:15). However, as noticed by John Sullivan, a world expert on Classical Nahuatl morphology (personal communication), *tempoloa* may as well be derived from the verb *tēmi* [te:mi] "to fill something, to stuff something" (Karttunen 1922: 222) or *tēma* [te:ma] "to cause something to fill up, to pour something into container" (Karttunen 1922: 221). [13]

Nevertheless, post-SPE developments in the theory of sound representation offer a new set of analytical tools which can be used to explain the distribution of nasal consonants in Classical Nahuatl without resorting to exceptional marking. These will be described in the following section. Moreover, notice that

[13] Notice that assuming that *on-* is somehow exceptional invalidates the use of the examples in (7) to contradict rules (11) and (12). This means that //an// would still be a possible underlying representation for the 2 PL SUB prefix. I reject this hypothesis on the grounds of economy and phonological naturalness. If //an// were underlying, the labializing environment would never constitute a natural class as the change would occur before vowels and some consonants. No matter which phonological model would be considered, labialization would have to be expressed by two distinct processes – one for pre-consonantal and one for pre-vocalic environments. As the analysis done so far shows, the alternation is undoubtedly clearer if the underlying form contained the labial nasal. Moreover, the Feature Geometry model in section 3.5 definitively confirms that assumption.

example (21) suffers from the Duke-of-York problem, which is successfully avoided in the DOT framework in section 4.3.

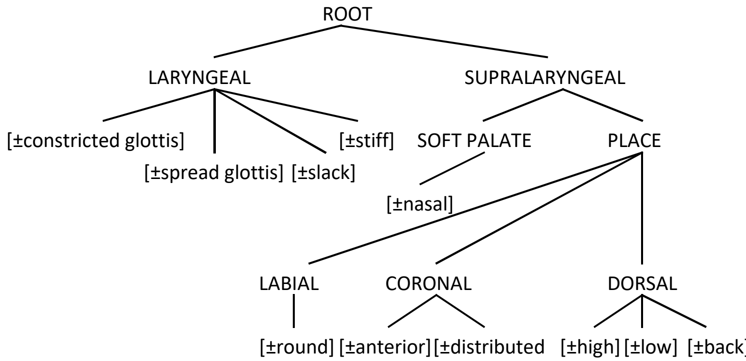
3.5. Feature Geometry

The SPE representation of sounds was based on the assumption that distinctive features are unordered and unrelated entries creating two-dimensional matrices used to identify particular phonemes. The lack of ordering implies that any two features are as related to each other as they are to any other features. As seen in previous sections, the sound [m] is described by means of the whole set of [+consonantal], [+nasal], [+anterior], [–coronal] and so on. In consequence, the analyzed change from a labial to coronal place of articulation of nasal sounds needs to be described in terms of two formally unrelated features: [±anterior], [±coronal]. However, these two features describe nothing but place of articulation.

Another problem related to this type of representation is that [±anterior] and [±coronal] are typically both involved in a common process of nasal assimilation, which forces a nasal segment to completely assimilate to the place of articulation of the following sound. Noticing this cross-linguistically well-attested process using two independent features would make it appear unnecessarily complex. As noted by Schane (1984), a widespread process should be represented in a simple way. He postulated the ”mirror principle" which requires the representation of a process to be thorough and full in a way that it must reflect the nature of a phenomenon in its full scale using as few elements as are necessary to provide a full representation of its nature and manner of occurence. The issue of excessive complexity resulting from the use of unordered feature matrices was noticed by Clements (1985) and Sagey (1986), who successfully introduced a three-dimensional hierarchical structure into the phonological representation of sounds.

Feature Geometry introduced a hierarchical order of features collected in larger nodes. For the purpose of this paper, I will use the Halle-Sagey model of representation (Sagey 1986; Halle 1992), as presented in (24). A phonological rule may now be realized as the interaction of whole nodes, rather than single features. In addition to feature changes, the new model of feature representation allows for expressing new types of processes: delinking, spreading, and spreading cum delinking.

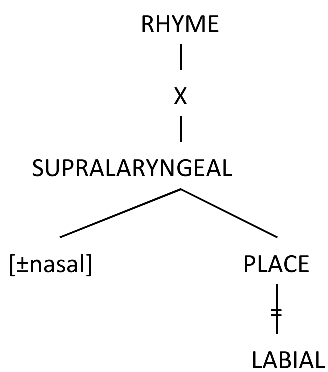
(23) The Halle-Sagey model of sound representation (Sagey 1986: 61)



The node that is most relevant to the present analysis is the PLACE node, which consists of an organized set of all distinctive features related to the place of articulation. The introduction of the PLACE node allows to express the aforementioned process of place assimilation in a simple way, in terms of delinking of the PLACE features, and acquiring new features through spreading from a neighbouring sound. The process is now clear and simple, rather than obscure and complex, which reflects its naturalness.

Using the feature geometry model of sound representation, the Coda Delabialization rule can be expressed as in (24) below (all nodes irrelevant from the point of view of the analyzed process have been omitted).

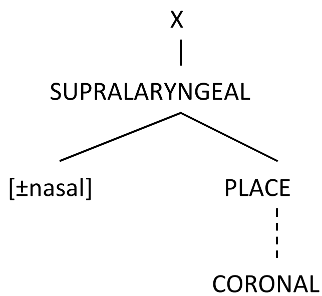
(24) Coda Delabialization – version 2



As a result of delinking of the feature LABIAL, the nasal loses its place of articulation becoming a placeless nasal /N/. Since all underlying nasals are realized as alveolar at the surface level, it is clear that the placeless segment must acquire a new place feature. This can be achieved by adopting Kiparsky's

(1985) claim that placeless segments are assigned the CORONAL place of articulation by default (26).

(25) Nasal Place Default



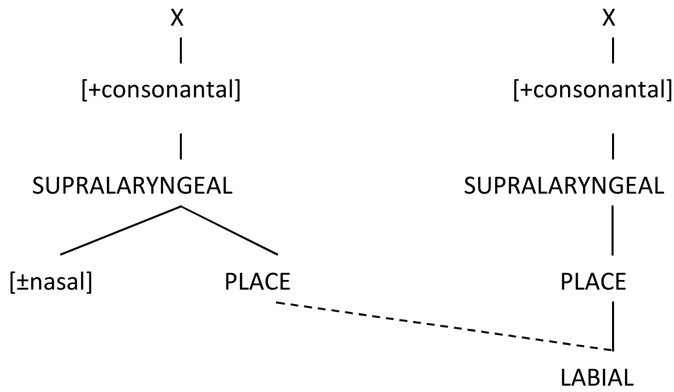
The feature geometry versions of Coda Delabialization (25) and Nasal Place Default (26) can be successfully applied to the examples in (4b) and (6b), as shown in (27).

(26) The derivation of *nen* (6a) and *ankitta* (7b)

//nem//	//am+k+itta+ʔ//	
/nem/	/am.kit.taʔ/	| *Syllabification*
/neN/	/aN.kit.taʔ/	| Coda Delabialization – version 2
/nen/	/an.kit.taʔ/	| Nasal Default Place
[nen]	[ankittaʔ]	

The derivation in (26) is analogous to the one in (19), which had a crucial flaw – the SPE based rule of Coda Delabialization (18) neutralized the difference between the underlying and derived syllable-final nasals. This is not the case in the feature geometry approach, as the underlying alveolar //n// retains its place of articulation, while the labial //m// loses it, becoming a placeless nasal segment. It is now possible to postulate a new rule that applies only to forms with an underlying final labial nasal by ordering it after Coda Delabialization and before Nasal Place Default. This new Labial Spreading rule (27) has to be specified as affecting placeless nasal segments.

(27) Labial Spreading



With the addition of the Labial Spreading rule (27), the derivation of forms such as [ammotta], where the PLACE node is shared by two neighbouring nasal segments (6a), and [konmaka] (7b) would be expressed as follows (28):

(28) The derivation of *ammotta* (6a) and *conmaca* (7b)

//am+mo+tta+ʔ//	//k+on+maka//	
/am.mot.taʔ/	/kon.ma.ka/	| *Syllabification*
/aN.mot.taʔ/	--------	| Coda Delabialization ver 2
/am.mot.taʔ/	--------	| Labial Spreading
--------	--------	| Nasal Default Place
[ammottaʔ]	[konmaka]	

As seen in (28), the introduction of feature geometry leads to the generation of proper surface forms containing a morpheme-final labial nasal in the UR, while not inducing any change of the underlying morpheme-final alveolar nasal. However, with this set of rules, a potential word *//panpa// would surface as *[panpa], as the underlying coronal nasal will not be neutralized and, in consequence, there would be no environment for spreading. This means that the rules would not account for the observed lack of the word-internal [n] before labial consonants, as in (5), and the word-internal distributional limitation would be treated as an accidental gap. The lack of morpheme-internal /n/ before bilabials may mean that such pairing is not found at the underlying level. It is possible that an older process, inactive in the known form of Classical Nahuatl, caused assimilation of morpheme-internal nasals which led to the restructuring of the URs in a way that morpheme-internal nasals must agree in place with the following consonant even before any rules are applied. The process then became void and inactive, however its by-products remained and became the new URs.

However, if *on-* were marked as an exception, the rule in (24) might be generalized to all nasals. This solution would account for both morpheme-internal and morpheme-final nasal distribution, excluding a single exceptional morpheme. This issue is successfully avoided by a later analysis in the DOT framework.

3.6. Interim Summary

As seen throughout the analysis presented in section 3, different approaches and rule-based models offer various solutions to the issue of nasal alternations found in Classical Nahuatl, but all of them have some drawbacks. The strict SPE model can successfully be used in order to generate all and only proper SRs, however the process of delabialization must be expressed in terms of a number of rules which cannot be unified. Adding the syllable structure allows for such a unification. More precisely, it makes it possible to express the fact that all alternations of nasal consonants in Classical Nahuatl are caused by delabialization which takes place in the syllable coda. However, including syllable structure into an analysis causes overapplication of rules, which results in generating unattested SRs containing the prefix *on-* (which may only be avoided by marking this prefix as exceptional). Last, but not least, the use of the Feature Geometry model results in proper surface forms in all instances where alternations may be noticed, however it fails to explain distributional limitations fully. Comparing the Strict SPE approach and the Feature Geometry model we face a tradeoff between a thorough explanation of the distributional facts of Classical Nahuatl, and simplicity of form regardless of the presentation of the delabializing process.

4. Constraint-based analysis

The introduction of Optimality Theory fundamentally changed the way in which phonological generalizations are expressed. As opposed to the rule-based model, the constraint-based analysis does not rely on rules, which must apply in a strict sequence in order to reach the surface representation. Instead, it is based on the assumption that languages operate through an interaction of violable constraints, which require the output forms to behave in specific, often contradictory, ways. For every underlying form, a set of possible output candidates is created. Only one candidate may survive an evaluation based on a language-specific sequence of ranked constraints and become the surface form, by incurring the least costly violations

Although the introduction of OT brought about a major shift in phonological research, there are some similarities between OT and the previous, rule-based frameworks. Notably, both OT and SPE assume at least two levels of representation: the input level (the UR) and the output level (the SR). In practical terms, this means that the Underlying Forms arrived at in section 3 can be assumed to be the input forms in an OT analysis. What remains to be done, then, is finding the appropriate constraints and establishing their ranking.

4.1. Coda Neutralization

OT divorces structural description from structural change. The latter is expressed by markedness constraints, which require or prohibit specific surface configurations. Constraints cannot be created arbitrarily, so as to suit the description of a particular language-specific change. Rather, their formulation must be based on cross-linguistic observations of universal phonological tendencies.

A perfect example of the universality of constraints is expressed by the ordered set of markedness constraints *PL(LAB, DOR) » *PL(COR)[14] which favor segments with the coronal place of articulation over others. Their ranking reflects a cross-linguistic observation that Dorsal and Labial place features are more marked than Coronal (Prince and Smolensky 1993; Lombardi 1997). Such markedness reveals itself in many ways. For example, dorsal and labial sounds suffer from more contextual restrictions than coronals.

If a language used only markedness constraints, all input forms would be paired with unmarked forms. This does not happen, however, due to the existence of faithfulness constraints which require candidates to be identical to the input. As markedness constraints *PL(LAB, DOR) » *PL(COR) concern the place features, the IDENT(PLACE) constraint is the most relevant one to prevent candidates too distant from the input from winning.

(29) IDENT(PLACE) (after: McCarthy 2008)
Let input segments=$i_1i_2i_3...i_m$ and output segments=$o_1o_2o_3...o_n$.
Assign one violation mark for every pair (i_x, o_y), where
i_x is in correspondence with o_y, and
i_x and o_y have different specifications for Place.

In Classical Nahuatl, IDENT(PLACE) has to be ranked higher than *PL(LAB, DOR) and *PL(COR). Otherwise, labial and dorsal segments would never appear in the output forms, contrary to the facts.

The easiest way to satisfy the place markedness constraints is by having a candidate containing a segment without any place of articulation.[15] Since surface

[14] *PL(LAB) – assign a violation mark for every instance of the labial node; *PL(DOR) - assign a violation mark for every instance of the dorsal node; *PL(COR) - assign a violation mark for every instance of the coronal node;

[15] Place markedness constraints can also be satisfied by deletion of a segment with place features. For the sake of clarity (since the forms in question do not exhibit epenthesis or elision), I assume that MAX and DEP, which prevent deletion and epenthesis, respectively, are undominated. All candidates violating those constraints will therefore be omitted in tableaux throughout the analysis.

forms containing a placeless segment are not observed in Classical Nahuatl, the survival of such candidates has to be avoided. This can be done by adding a HAVEPLACE constraint (32) to the ranking.

(30) HAVEPLACE (McCarthy 2008, Padgett 1995)
Assign one violation mark for every segment that has no Place specification.

HAVEPLACE must be ranked higher than the markedness constraints that prohibit individual place nodes. The motivation for this ranking is illustrated by the evaluation of the 2 SING POSS prefix *mo-* //mo// in tableau (31).

(31) HAVEPLACE » IDENT(PLACE) » *PL(LAB, DOR) » *PL(COR)

//mo//	HAVEPLACE	IDENT(PLACE)	*PL(LAB, DOR)	*PL(COR)
☞ a. mo			*	
b. No	*!	*		
c. no		*!		*

The candidate with a placeless nasal (31b) violates the HAVEPLACE constraint and is eliminated. Since candidate (31c) contains a coronal nasal, not found in the input form, it violates the IDENT(PLACE) constraint. As a result, only the fully faithful candidate (31a) survives the evaluation. As place identity is more important than violating the *PL(LAB) constraint, candidate (31a) still emerges as the optimal output form.

The ranking established in (31) forbids changes in place of articulation in any position. Therefore, another constraint, ranked higher than IDENT(PLACE), needs to be introduced in order to allow for and force changes in place features. As observed in Section 3.4, the changes are found only in the coda position. This situation is not uncommon. As noticed by Goldsmith (1990: 25), the contrasts found in the syllable coda are fewer than those in other parts of the syllable. However, whatever contrasts are to be found in the coda, they are a subset of the contrasts found in the first part of the syllable. In OT, this observation is expressed in the form of the CODACONDITION constraint (Selkirk 1982; Itô 1986).

(32) CODACONDITION (after McCarthy 2008: 279)
Assign one violation mark for every token of Place that is not associated with a segment in the syllable onset.

If such a general constraint were highly ranked in Classical Nahuatl, one might expect fewer place contrasts in the coda. This is, however, only true for nasal consonants. The distribution of other segments is not equally restricted. Thus velar [k] (*icpalli* [ik.pal.li] "seat", NW: 219), coronal [t] (*catca* [kat.ka] "was", NW: 213) and bilabial [p] (*cuaqueptoc* [kwa.kep.tok] "someone crazy", Karttunen 1992: 60) are unexceptionally allowed in the coda position.

In order to reflect the observation that only nasal segments in the syllable coda tend to alternate, the constraint could be limited to nasals only, as in (33).

(33) NASALCODACONDITION (NCC)
Assign one violation mark for every token of a nasal segment's Place that is not associated with a segment in the syllable onset.

One might be tempted to assume that constraint (33) solves the issues presented above. However the evaluation of *nem* in tableau (34) shows that the introduction of this constraint is not enough.

(34) HAVEPLACE » NCC » IDENT (PLACE) » *PL(LAB, DOR) » *PL(COR)

//nem//	HAVEPLACE	NCC	IDENT (PLACE)	*PL (LAB,DOR)	*PL(COR)
☜ a. nem		*		*!	*
b. neN	*!		*		*
☹ c. nen		*	*!		**

As presented in tableau (34), candidate (34b) containing a placeless segment immediately violates the HAVEPLACE constraint and is thus eliminated from the competition. Both the fully faithful candidate (34a) and the desired winner (34c) violate the NASALCODACONDITION constraint, as they both contain segments in the coda and no following onset with which those segments would associate their place features. Consequently, contrary to the initial intuition, NCC fails to differentiate between the two candidates. As a result, the choice between them is passed on to lower-ranked constraints. Candidate (34c) violates the IDENT (PLACE) constraint by containing a coronal nasal segment while the one in the input is labial. The lower-ranked *PL(LAB) constraint is violated by the labial nasal in the coda of candidate (34a). Candidate (34a) is then incorrectly selected as the optimal one, as indicated by the ☜, whereas the desired winner, candidate (34c), loses by not being faithful, which is marked with a ☹.

As seen in tableau (34), the NCC constraint does not serve its purpose, as any candidate with a nasal segment in the coda position violates it. The evaluation reaches its conclusion at the level of the IDENT (PLACE) constraint, which always favours candidates containing the segment from the input (therefore preventing any alterations). This issue may be resolved by making the NCC constraint more specific.

(35) NCC(lab)
Assign one violation mark for every token of a labial node that is not associated with a segment in the syllable onset

If the ranking established in (34) is kept, replacing NCC by its more specific version will result in the proper choice of output forms. The evaluation of forms containing prevocalic [m], as in (31), will remain unchanged, as there is no nasal coda to be influenced by any variation of NCC. The competition is resolved through violation of Ident(place). In the case of //nem//, only candidate (34a) violates NCC(lab). Candidate (34c), which violated NCC in (34), satisfies the more specific version of this constraint stated in (34), and as a result emerges as the winner, as shown in (36) 16.

(36) HAVEPLACE, NCC(LAB) » IDENT(PLACE)

//nem//	HAVEPLACE	NCC(LAB)	IDENT(PLACE)
a. nem		*!	
b. neN	*!		*
☞c. nen			*

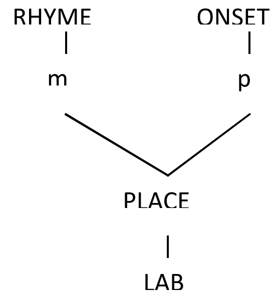
In this tableau, candidate (36b) violates the HAVEPLACE constraint instantly by containing a placeless nasal and is the first to lose the competition. The choice is now made between the fully faithful candidate (36a) and the candidate with the coronal nasal (36c). The newly introduced NCC(LAB) constraint ameliorates the previous evaluation shown in tableau (34) by affecting only candidate (36a) with a labial nasal in the coda position, which violates it and loses the competition. Even though candidate (36c) violates the IDENT(PLACE) constraint because of the change of labial [m] to coronal [n], it emerges as the winner.

4.2. Nasal Place Assimilation

Let us draw attention to the fact that constraint (35) can be satisfied not only when the offending labial node is removed but also when it is shared with the following consonant occupying the onset position, as illustrated in (37).

[16] One of the reviewers suggested that tableau (36) cannot eliminate a candidate with the velar nasal [neŋ]. However, tableau (36) is a variant of tableau (34) used to show the consequence of the application of the specific NCC(LAB) constraint. The markedness constraints from (34), which express the preference of the coronal nasal over the velar one, still exist in the system but have been omitted for a clearer presentation of a new constraint.

(37) Place Sharing



As a result, NCC(lab) can act as a trigger for both place change and place assimilation. As a matter of fact, the ranking established so far derives the correct output form for words such as ampāquiuh, as presented in tableau (38) below.

(38) NCC(LAB) » IDENT(PLACE) » *PL(LAB, DOR) » *PL(COR), NCC

//am+pa:ki+ʔ//	NCC (LAB)	IDENT (PLACE)	*PL(LAB, DOR)	*PL(COR)	NCC
a. am.pa:.kiʔ	*!		***		*
b. an.pa:.kiʔ		*!	**	*	*
☞c. am͜.pa:.kiʔ			**		
d. an͜.ta:.kiʔ		*!*	*	*	

The specific NCC(LAB) is violated by candidate (38a) with a labial nasal in the coda, that is not simultaneously associated with an onset. Notice that place sharing saves candidate (38c) from violating NCC(LAB) as the labial place feature of the coda is associated with the one of the following onset. Given the definition for IDENT(PLACE) in (29), candidate (38d) exhibiting place sharing violates the IDENT(PLACE) constraint twice, as both nasal in the coda and the stop in the onset changed their place specification to coronal, while the ones in the input are both labial. Moreover, the same constraint is also violated by candidate (38b). Since (38c) does not violate the Identity constraint, both candidates (38b) and (38d) are eliminated, and candidate (38c) is therefore selected as the optimal output form.

The same ranking predicts correct surface forms for words in which the labial nasal of the prefix assimilates to match the coronal place of the initial consonant of the verb stem. as shown by the derivation of *antlaca* [antłaka] in (39).

(39) NCC(LAB) » IDENT(PLACE) » *PL(LAB, DOR) » *PL(COR), NCC

//am+tłaka //	NCC (LAB)	IDENT (PLACE)	*PL(LAB, DOR)	*PL(COR)	NCC
a. am.tła.ka	*!		**	*	*
b. an.tła.ka		*	*	**!	*
☞c. an͜.tła.ka		*	*	*	
d. am͜.pa.ka[17]		*	**!		

The fully faithful candidate (39a) violates the NCC(LAB) constraint by having a labial nasal in the coda position before an onset with a coronal consonant. The IDENT (PLACE) constraint is violated once by each remaining candidates: candidates (39b) and (39c) change the place feature of the nasal in the coda from labial to coronal, while candidate (39d) changes the place of the coronal segment in the onset to labial. Therefore, the choice of the optimal candidate must be made through the lower-ranked constraints. Candidate (39d) violates *PL(LAB, DOR) twice – once for the velar place of articulation of the velar plosive and once for the shared labial place. The two candidates (39b) and (39c), which caused a single violation for the velar plosive, remain. The both remaining candidates are phonetically identical, although structurally they are different. In candidate (39b) the alveolar nasal has its own coronal node, whereas in candidate (39c), the coronal node is shared between the nasal and the following consonant. Candidate (39c) fares better than candidate (39b) on both *PL(COR) and NCC as the shared place node causes one violation to *PL(COR) and does not violate the NCC constraint. As a result, it emerges as the surface form.

As it stands, the ranking used in (38) and (39) would generate the wrong output form for words such as *anquitta* [an+k+itta+ʔ], as it would predict *[aŋ͜.kit.taʔ] as the surface representation. According to the assumptions made in Section 2, the velar nasal segment does not appear in Classical Nahuatl either as a phoneme or an allophone. As a result, the *[ŋ] constraint needs to be added to the evaluation. This segment inventory constraint prevents any output forms with the velar nasal from winning. Since no words containing such a sound are found in Classical Nahuatl, *[ŋ] must be undominated in the language, just like HAVEPLACE. Tableau (40) presents the correct evaluation of *anquitta*.

[17] As has been noticed by many scholars, the process of place assimilation is in most cases regressive (see: Webb 1982, Ohala 1990, Mohanan 1993, Jun 1995, 2004; and Steriade 2001). Since the directionality of the assimilation issue is orthogonal to the point under discussion, candidates exhibiting progressive assimilation will not be included in further analysis. The standard solution to this issue is positional faithfulness, as proposed in Casali (1997) and Beckman (1997). Some recent proposals for solving the issue of directionality can be found in McCarthy (2008) and Wilson (2010).

(40) *[ŋ], NCC(LAB) » IDENT(PLACE)

// am+k+itta+ʔ//	*[ŋ]	NCC (LAB)	IDENT (PLACE)
a. am.kit.taʔ		*!	
☞b. an.kit.taʔ			*
c. aŋ.kit.taʔ	*!		*

In contrast to tableaux (38) and (39), the candidate with a shared place of articulation (40c) is the first to be eliminated due to its violation of *[ŋ]. The choice has to be made between the fully faithful (40a) and (40b) with a coronal nasal. The former violates the NCC(LAB) constraint as it contains a labial [m] in the coda, and therefore is eliminated. The remaining (40b) emerges as the surface form, even though it violates the identity constraint. Interestingly, the winner of the evaluation in (40) does not exhibit place sharing as the winning candidates (38c) and (39c) do, but contains a full coda nasal, penalized by NCC. This is due to the sound inventory of Classical Nahuatl which does not contain the velar nasal. If the velar segment were present in the language, the evaluations would present a regularity in every instance. However, it is still possible to derive proper surface forms without any modifications in the ranking, despite the limitations of the sound inventory.

Finally, the established ranking results in selecting proper surface forms for words containing the directional prefix *on-*. The prefix does not undergo changes as it violates none of the highest ranked constraints. NCC(LAB) does not trigger neutralization of the coronal nasal from the input. The fully faithful candidate never violates the NCC(LAB) constraint, nor the IDENT(PLACE), and wins the evaluation, as illustrated in tableau (41).

(41) NCC(LAB) » IDENT(PLACE) » *PL(LAB, DOR) » *PL(COR), NCC

// k+on+maka//	NCC (LAB)	IDENT (PLACE)	*PL(LAB, DOR)	*PL(COR)	NCC
a. kom.ma.ka	*!	*	****		*
☞b. kon.ma.ka			***	*	*
c. kom͜.ma.ka		*!	***		

Candidate (41a), in which the labial nasal segment is associated solely to the coda position, violates NCC (LAB) and is eliminated. Since candidate (41c) exhibits a change of place from coronal in the input to labial in the output, it is bound to violate IDENT(PLACE). The evaluation is concluded by selecting (41b) as the winner without relying on the low-ranked place markedness constraints.

4.3. Morpheme-internal distribution

The constraint ranking established up to this point yields correct results for morphologically complex forms. It does not, however, select correct output forms of inputs containing morpheme-internal NC sequences. A hypothetical monomorphemic form containing an alveolar nasal followed by a bilabial stop is predicted to surface faithfully, as shown in tableau (42) below.

(42) HAVEPLACE, NCC(LAB) » IDENT(PLACE)

// panpa//	HAVEPLACE	NCC (LAB)	IDENT (PLACE)
☞a. pan.pa			
☹ b. pam.pa		*!	*
c. paN.pa	*!		*
☹ d. pam.pa			*!

The candidate with a placeless segment (42c) is eliminated after violating the high-ranked HAVEPLACE constraint. Needless to say, a candidate in which the nasal changes its place to labial, (42b), is eliminated by the NCC(LAB) constraint. The desired winner, candidate (42d) satisfies this constraint because the labial place node is associated with the following onset as well as the coda. However, NCC(LAB) is also satisfied by the fully faithful candidate (42a). Since (42d) violates IDENT(PLACE) by changing the place of the coronal nasal to labial, it is eliminated from the competition and, as a result, the fully faithful candidate (42a) is incorrectly identified as the winner.

This result is not consistent with the observation made in Section 2 that morpheme-internally, only [m] can appear before bilabials. Recall that the rule-based analysis faced the same problem. Coda Delabialization, Bilabial Spreading and Nasal Default Place were able to derive correct forms for word-final and morpheme-final nasals but not for the distribution of morpheme-internal NC sequences. At the end of section 3.5, it was suggested that the lack of coronal nasals before bilabials could be a residue of some earlier diachronic process, which would restructure the URs. Shifting the onus of explanation upon the shape of the lexicon is a viable option in rule-based phonology but not in OT, as it breaches one of its core tenets – the Richness of the Base principle (Prince and Smolensky 1993: 209). The principle states that every generalization needs to be expressed by constraint ranking, and that any constraints on input are disallowed. In other words, every possible input must be considered, and the attested forms must be selected as optimal on the basis of constraint ranking exclusively.

Given the Richness of the Base, //panpa// is an input to [pampa] that must be considered and, consequently, the evaluation in (42) has to be rectified. The only real solution to the issue presented in (42) would be to rank the general NCC constraint higher than its more specific version, NCC(LAB). This would eliminate not only candidate (42b) but also the incorrectly winning candidate (42a), as they both contain a nasal coda, with a place of articulation which does not match the place features of the following onset. At this point, only candidate (42d) would stand and would thus become the winner. However, such a ranking would also result in deriving *[kommaka] from //k+on+maka//, contrary to the observation made in (7). Therefore a ranking paradox is reached, as two distinct constraint rankings are necessary in order to reach correct results for morpheme-internal and morpheme-final nasals.

As a matter of fact, such an asymmetry between stem and word phonology is well established in the phonological literature. It may be traced back as early as the work of Jakobson, who notes that “affixes as grammatical morphemes... habitually differ from the other [lexical] morphemes by a restricted and selected use of phonemes and their combinations” (Jakobson 1965:29). Apart from inventory differences between roots and affixes, there may be phonotactic asymmetries. Booij (2011:2051-2052) discusses a number of constraints on a combination of segments in Arabic, Dutch and English that concern tautomorphic sequences exclusively. For example, clusters of voiced obstruents can never end English morphemes, however such instances occur at the end of words as an effect of affixation (**lovd* [lovd] vs. *loved* [lov+d]). The Classical Nahuatl data seems to exemplify the latter asymmetry, as [nm] is prohibited morpheme-internally but allowed across morpheme boundaries (as in *conmaca* [k+on+maka]).

Although well-documented, the root-word dichotomy is utterly ignored in classical Optimality Theory. One of the central tenets of the framework is strict *parallelism*, a principle which states that “[b]est-satisfaction of the constraint hierarchy is computed over the whole hierarchy and the whole candidate set.” (McCarthy and Prince 1994:3) This precludes the differentiation of root- and word-level phonology, since it means that forms at all levels of complexity have to be evaluated in parallel against the same constraint ranking. A number of scholars view this omission as a serious weakness of the theory and argue that OT needs to be extended to admit the possibility of level distinction between stems and words (as well as words and phrases and perhaps additional levels). This idea is implemented in LMP-OT (Kiparsky 1997, 2000), Derivational OT (Rubach 1997, 2000) and Stratal OT (Bermudez-Otero 2003, forthcoming). The crucial difference between these models and classic OT is the recognition of separate word, stem and phrase levels that may differ in terms of ranking. As will be shown below, adopting a different constraint hierarchy for stem level and word level evaluations solved the problem posed by the Classical Nahuatl data.

Since all morpheme-internal nasals agree in terms of place features with the following sound (with the exception of [k], as seen in (5c)), the ranking required at the stem level, at which lexical morphemes and suffixes are evaluated, is one that prohibits *any* place of articulation in coda nasals. Ranking HAVEPLACE low and forbidding place sharing will result in selecting a candidate with placeless nasals in the coda and at the end of the word as the output form.[18] The winning stem-level candidates become the word-level input forms. At this level they are evaluated along with prefixes (which crucially are not evaluated at the stem level). Since the /n/ in prefixes never assimilates to the following sound, the constraints used at stem-level must be slightly re-ranked at the word-level. NCC, penalizing each instance of place features is demoted, while NCC(LAB) becomes the constraint responsible for the assimilation of underlying nasals. Default nasals are also chosen at this level – the HAVEPLACE constraint becomes undominated and markedness constraints choose [n] as the least marked option.

Tableaux 44-45 illustrate the two-stage evaluation of a monomorphemic word containing an NC cluster. At the stem level, the ranking bans any place of articulation in coda nasals through the highly-ranked NCC. Additionally, *MULT-LINK prohibits node sharing (Rubach 2000:288).

(43) *MULT-LINK
Assign one violation mark for each instance of PLACE node linked to more than one segment.

Since HAVEPLACE is ranked low, the evaluation always results in a placeless nasal in the coda position.

(44) Level 1
*MULT-LINK, NCC » IDENT(PLACE) » *PL(LAB, DOR) » *PL(COR), NCC(LAB), HAVEPLACE

// panpa//	*MULT-LINK	NCC	IDENT (PL)	*PL (LAB, DOR)	*PL (COR)	NCC (LAB)	HAVE PLACE
a. pan.pa		*!		**	*		
b. pam.pa		*!	*	***		*	
☞c. paN.pa			*	**			*!
d. pam͜pa	*!		*	**			
e. pan͜ta	*!		*	*	*		

The *MULT-LINK constraint is fatally violated by the two candidates with a shared PLACE feature (44d,e). Without the *MULT-LINK constraint, candidate (44d) would be preferred over candidate (44e) due to the universal ranking of *PL(LAB) » *PL(COR). However, Wilson (2001:149) noticed that this type of markedness-driven assimilation never occurs. Rather, it is always the first

18 In principle, markedness constraints could already force place sharing and choose [n] as the least marked option whenever sharing is not possible (before dorsals and word-finally). However, as will be shown below, the solution proposed here has an additional advantage of side-stepping the issue of directionality discussed by Wilson (2001) and McCarthy(2008).

consonant that assimilates. The removal of place features at this level solves this issue. A candidate in which the second consonant would be deprived of place of articulation cannot win in such a case, as it would never lead to the satisfaction of any higher-ranked constraint. It would be a gratuitous violation, while any violations in OT must be minimal (McCarty and Prince 1994:4). Two candidates with an independent nasal segment in the coda (44a,b) incur a single violation each of the NCC constraint, and are thus disqualified. The last candidate standing is the one with a placeless nasal (44c). The same constraint ranking would also result in selecting a candidate ending with a placeless nasal segment (e.g. [nem] → [neN]).

The output of the stem-level becomes the input for word-level evaluation, at which HavePlace is undominated to force place acquisition, and *MULT-LINK is ranked lower in order to allow candidates in which nasals share place nodes with the following sound. Moreover, to explain the dispreference of labial nasal codas, the ranking of NCC and NCC(LAB) is switched.

(45) Level 2
HAVEPLACE » » IDENT(PLACE) » *PL(LAB, DOR) » *PL(COR), NCC, *MULT-LINK

// paNpa//	HAVE PLACE	NCC (LAB)	IDENT (PL)	*PL (LAB, DOR)	*PL (COR)	NCC	*MULT-LINK
a. pan.pa			*	**	*!	*	
b. pam.pa		*!	*	***		*	
c. paN.pa	*!			**			
☞d. pam͜.pa			*	**			*

At word level, the fully faithful candidate with a placeless segment (45c) is disqualified through a violation of the now undominated HAVEPLACE. The candidate with an independent labial nasal in the coda (45b) is eliminated as it violates NCC (LAB). Now, since the input contained a placeless segment, all output forms except for the fully faithful (already eliminated) candidate (45c) cause violations of IDENT (PLACE) at least once, as they add place features to nasals in the coda position. At this point there are two candidates left: (45a) with an independent coronal nasal in the coda, and (45d) in which the labial node is shared between the nasal and the following stop. The choice is made solely on the grounds of place markedness constraints. Both candidates violate *PL(LAB) twice: candidate (45a) incurs violations for each of its two labial plosives, and (45d), even though it contains three labial segments, violates the *PL(LAB) constraint once for the labial place of the initial plosive and once for the labial place shared by the nasal coda and the plosive onset. Since candidate (46a) incurs an additional violation of *PL(COR) by containing a coronal nasal, it is eliminated and, as a result, candidate (45d) emerges as the winner.[19]

Let us now turn to the analysis of a word in which the NC sequence spans two morphemes, such as *conmaca* [k+on+maka] "He gives it to him." At the stem level, only the root, //maka// is evaluated. [maka] is chosen as its output, since there is no need for any change. At the word level, the evaluation covers both the optimized stem and prefixes. The evaluation at the word level is shown in tableau (47).

(46) Level 2
HAVEPLACE » NCC(LAB) » IDENT(PLACE) » *PL(LAB, DOR) » *PL(COR)

/k+on+ma.ka/	HAVE PLACE	NCC (LAB)	IDENT (PLACE)	*PL (LAB, DOR)	*PL (COR)
☞a. kon.ma.ka				***	*
b. kom.ma.ka		*!	*	****	
c. koN.ma.ka	*!		*	***	
d. kom.ma.ka (shared)			*!	***	

Candidate (46c) with a placeless nasal is eliminated by violating the undominated HAVEPLACE constraint. The candidate with an independent bilabial nasal in the coda incurs a single violation of the NCC(LAB) constraint, by which it becomes disqualified. Candidate (46d) in which the place node is shared by two segments violates the IDENT(PLACE) constraint, as the coronal nasal of the *on-* prefix changed to labial due to the place sharing. The last candidate standing is the fully faithful (46a). Notice how the highly-ranked NCC(LAB) prevents assimilation of underlying coronal nasals, and compare it to the general NCC, undominated at the stem level, which favours neither of the two nasals.

4.4. Interim Summary

Given the analysis provided in this section, it can be noticed that the change from the input to the output forms is caused by two operations – delabialization and assimilation. Both processes are triggered by a single driver, the prohibition of independent place features in the coda position, expressed by the CODACONDITION. Crucially, a place node shared by the segment in the syllable coda and the segment in the onset satisfies the CODACONDITION. The coronal place of articulation of nasals at the word boundary and in the instances in which

19 If the input happened to be a morpheme ending in a placeless nasal, the candidate with final [n] would be chosen as the least marked one by the *PL(LAB) » *PL(COR) ranking.

assimilation is not possible stems from the fact that coronal is the least marked place.

However, as has been shown, standard OT cannot provide a solution for different generalizations morpheme-internally and across morpheme boundaries. They may, however, be accounted for through assuming different constraint rankings for the stem- and word-level. The ranking required at the stem-level prohibits *any* place of articulation in coda nasals. As a result, candidates with placeless nasals in the coda are chosen as the optimal ones, and become the input for word-level evaluation. Since the word-level ranking is different and NCC (LAB) is ranked high while NCC is demoted, only bilabial nasals are banned in the coda. Consequently, the underlying /n/ in the prefix does not assimilate to the following sound as /m/ does. Since the HAVEPLACE constraint is undominated at this level, all sounds must have a place of articulation and any placeless segments need to acquire a new one. The acquired place is either the one of the following sound. If this is not possible, the least marked place of articulation emerges.

The ranking established in 4.2 expresses the observation that labial nasal codas are allowed only under strict conditions. A candidate with a labial nasal coda is able to survive the evaluation only if the nasal coda shares the labial place features with the following sound. On the other hand, if the following sound is not labial, the evaluation ends with a choice of one of the candidates with the coronal nasal, with or without shared place. The DOT analysis shows a possible solution for the morpheme-internal distribution of nasals.

5. Conclusions

The two nasal segments found in Classical Nahuatl – labial [m] and coronal [n] – have limited distribution in the coda position. Morpheme-internally, nasal codas always agree in terms of place of articulation with the following segment, with the exception of the velar [k], before which only the coronal nasal may appear. Across morpheme boundaries, however, the occurrence of [n] is not environmentally restricted. Moreover, the word-final position is reserved for the coronal nasal only.

The rule based analysis in section 3, depending on the approach taken, may provide partial explanations to the observed generalizations. Although a strict SPE account makes it possible to derive the correct surface forms for all the data, it has serious drawbacks in terms of parsimony and explanatory power. Firstly, three ununifiable delabialization rules need to be posited. Secondly, the observation that the alternations are related to the coda position remains unexpressed. Nevertheless, while taking syllable structure into account does permit a unification of the three delabialization processes, the analysis yields incorrect surface forms for the directional prefix *on-*, as it predicts that it should undergo place assimilation before labials. This problem can be solved if the rules are recast in terms of Feature Geometric processes of spreading and delinking. This comes at a price, however. Although the analysis correctly predicts that the coronal nasal in the directional prefix should not alternate, it makes the same prediction for morpheme-internal nasals. As a result, the lack of coronal nasals before bilabials within morphemes is unexplained.

A constraint-based analysis discussed in section 4, however, is able to unify all delabialization processes using a single driver. Moreover, it explains the choice of [n] where the assimilation cannot occur. Standard OT, however, is unable to provide a solution for all generalizations, as it does not recognize the difference between stem- and word-level phonology. Acknowledging two levels of derivations which differ in constraint ranking solves this issue. Stratal OT seems to be the most suitable framework to provide a description of Classical Nahuatl data. First of all, it generates all and only attested surface forms. Secondly, all processes are triggered by a single trigger – the prohibition of place features in the coda.

The empirical advantage of OT, however, is based on the assumption that the generalizations described in section 2 actually formed the phonological knowledge of Classical Nahuatl speakers at a single stage of the language development. However, there is a possibility that the described morpheme-internal or morpheme-boundary distribution was an accidental gap.

One way to eliminate the necessity of levels would be to argue that all prefixes assimilate and the directional prefix *on-* is marked as exceptional, as suggested in section 3.4. The discussion leading to the rejection of this hypothesis illustrates that a generative analysis of data found in descriptive sources not only provides an explanation of the facts but may also provide additional guidelines for researchers preparing those sources.

Another way to simplify the analysis would be to argue that the lack of coronal nasals before bilabials is an accidental property of the Classical Nahuatl lexicon. As suggested in section 3.5, it could be the case that at the described stage of Classical Nahuatl development, the rule of assimilation applied only to bilabial nasals. In the past, however, an assimilatory rule might have applied to all nasals, which could lead to restructuring of underlying representations. Such a hypothesis might be tested in a number of ways. Firstly, it would imply that the directional prefix *on-* was added to the lexicon after the rule of Nasal Assimilation became inactive and thus its UR was unaltered. This could be corroborated by analyzing the dating of the prefix. Secondly, if the rule of Nasal Assimilation were inactive, it should in principle be possible to find words containing non-assimilated coronal nasals before bilabials. Thus, a detailed search of the Classical Nahuatl lexicon to find words which emerged in the period may help to settle the issue. Finally, as argued by Ohala (1986), determining whether a gap is systematic or accidental may be done by examining external evidence, such as borrowings, nativization, speech errors or word games. However, to obtain such evidence, it would be necessary to test phonological the competence of a native speaker of Classical Nahuatl. Needless to say, this is out of the question because the language in its classical form is considered extinct. What could be done, however, is an analysis of contemporary dialects of Nahuatl to see if all nasals assimilate. Thus, the analysis presented in this paper opens up new unexplored paths for the investigation of past and present languages related to Classical Nahuatl. This, however, cannot be covered in this work and must await further research.

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